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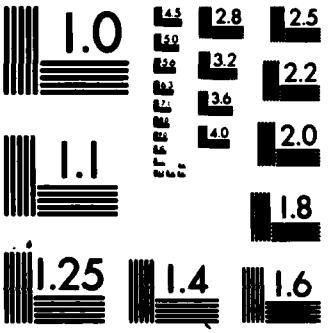

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Stable Hybrid Model Reference Adaptive Control Algorithms are suggested which are then extended to deal with the presence of bounded disturbances. The question of unmodelled dynamics is also addressed. Simpler adaptive control algorithms are developed in the context of pole placement, by first considering systems with known parameters. Such algorithms do not require a minimum phase assumption. The foundation is laid for a much broader investigation of robust design methods for systems with structured uncertainties.

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Titled

RESEARCH IN ADAPTIVE CONTROL

HYBRID AND CONSTRAINED STRUCTURE SYSTEMS

(May 1, 1980 through August 31, 1983)

Report Number AFOSR-80-0155-FSR

By

T. E. Djaferis, Co-Principal Investigator

I. RESEARCH OBJECTIVES

A tremendous research effort has been directed over the last two decades by Modern Control Engineers in the development of system design methodologies. The objective was to use these tools for the control of modern, complex systems and to increase performance. It is also true however that only models of physical systems are available, which on many occasions are quite "crude". It is imperative therefore that design techniques are suggested which address the imprecise, approximate or changing nature of the model. Adaptive control offers one such viable alternative design method.

In recent years several important theoretical questions concerning the stability of Adaptive Control systems have been resolved. Once that was accomplished emphasis of the research in this area shifted to addressing the gap between theory and practice. If there was to be a wider acceptance and applicability of adaptive algorithms other important issues had to be addressed such as rate of convergence, robustness, a priori information, and computational complexity.

The major research objectives of our research effort over the last three years were the following:

1) To develop stable Hybrid Model Reference Adaptive Control Systems.
2) To investigate the robustness of these systems in the presence of unmodelled dynamics and bounded disturbances.
3) To develop simpler adaptive control algorithms, allowing for an easier implementation.
4) To investigate the application of Adaptive Control Algorithms to non-minimum phase systems.

II. RESEARCH ACCOMPLISHMENTS

It is our feeling that substantial research contributions have been made possible, over the last three years under AFOSR Grant Number 80-0155. A list of all publications generated through either total or partial support of this grant is included in Section IV.

Historically Adaptive Control algorithms have either been developed for continuous time or discrete time systems. In Hybrid Model Reference Adaptive Control the adaptive gains for a continuous time system are adjusted on a discrete time basis. The appeal of such a technique comes from the convenience of implementation, by performing gain calculations on a fast digital computer. References [1] and [2] suggest two different solutions to the Hybrid Model Reference Problem. Both guarantee stability of the overall system. This effort represents a successful answer to objective I-1. The methods were extended to deal with the presence of bounded disturbances, and the issue of unmodelled dynamics was investigated. References [3] and [4], include this work and address objective I-2.

Any Adaptive Control Algorithm represents an adaptive implementation of a corresponding algorithm designed for a system with known parameters. As a result any improvement of an algorithm for a known system can result in a corresponding improvement of the adaptive implementation. If for example one can suggest a method for pole assignment which requires a lower order compensator, this results in fewer parameters for estimation and a simpler adaptive algorithm. This is indeed what we accomplished in a series of papers on the problem of General Pole Assignment [7]-[11]. New constructive solutions were reported improving earlier results on the subject. The efforts culuminated in making simplifying suggestions for an Adaptive Pole Placement Algorithm, [12]. These results dealt specifically with

objectives I-3 and I-4.

Additional work was carried out on some computational aspects of Discrete Time Model Reference Adaptive Control [6] and the Global Stability of Direct Hybrid Adaptive Pole Placement [5].

Even though in the original proposal we had not envisioned work on Robustness of design methods for systems with known parameters, our investigations instigated an effort in this very important direction. Robust design methodologies are at the forefront of current research and with very good reason. References [13] and [14] include our first results in this area. We investigate the pole assignment problem when the system includes "structured" uncertainties.

It is our belief that this work represents a substantial research contribution which would not have been possible without AFOSR support. For this we thank our sponsors at AFOSR.

III. ASSOCIATED PROFESSIONAL PERSONNEL

Professors

Professor Richard V. Monopoli	May 1, 1980 - March 19, 1982
Professor Theodore E. Djaferis	May 1, 1980 - August 31, 1983
Professor Howard Elliott	August 1, 1982 - August 31, 1983

Graduate Students

Roberto Cristi (Obtained his Ph.D. in the summer of 1983)	May 1, 1980 - July 31, 1983
Sal Spada (Obtained his M.S. in the summer of 1982)	September 1, 1980 - April 30, 1982
Aswartha Narayana (Will be completing his Ph.D. in January 1984)	September 1, 1982 - August 31, 1983
Massoud Amin (Will be completing his M.S. in May 1984)	September 1, 1982 - April 30, 1983

The original Principal Investigator for this grant was Professor Richard V. Monopoli. We were all very saddened by his unexpected death in March of 1982. His leadership, enthusiasm and devotion to his work will be remembered. A memorial award will be given annually in the Department of Electrical and Computer Engineering, honoring his name.

IV. PUBLICATIONS GENERATED UNDER THIS GRANT

[1] R. Cristi, R. V. Monopoli, "Model Reference Adaptive Control Systems: The Hybrid Approach," Proceedings of the First American Control Conference, Arlington, VA, June 1982.

[2] R. Cristi, R. V. Monopoli, "A Stable Hybrid Adaptive Algorithm with Periodic Sampling and Gain Adjustment," Proc. of the 21st CDC, Orlando, Florida, December 1982.

[3] R. Cristi, "Hybrid Model Reference Adaptive Control Systems With Bounded Disturbances," Proc. Workshop on Adaptive Control, Florence, Italy, October 1982, to appear in Ricerche di Automatica.

[4] R. Cristi,"Robustness of the Error Model for Discrete Time Adaptive Control in the Presence of Unmodelled Dynamics," UMass Technical Report, submitted to the 3rd American Control Conference, San Diego, CA, June 1984.

[5] H. Elliott, R. Cristi, M. Das, "Global Stability of a Direct Hybrid Adaptive Pole Placement Algorithm," UMass Technical Report UMASS-ECE-NO82-1, to be presented at the 22nd CDC , San Antonio, Texas, December 1983, (submitted for publication to IEEE Trans. on AC).

[6] R. Cristi, R. V. Monopoli, "Computational Aspects of Discrete Time Model Reference Adaptive Control," IEEE Trans. AC, Vol. AC-27, No. 3, June 1982.

[7] T. E. Djaferis, "Generic Pole Assignment Using Dynamic Output Feedback," Int. J. Control, Vol. 37, No. 1, pp. 127-144, 1983.

[8] T. E. Djaferis, S. K. Mitter, "Generic Invariant Factor Assignment Using Dynamic Output Feedback," Linear Algebra and its Applications, 50: 103-131, 1983.

[9] T. E. Djaferis, "Another Approach to Generic Pole Assignment," Proc. of the 1982 IEEE CDC, Orlando, Florida, December 1982.

[10] T. E. Djaferis, A. Narayana, "A New Sufficient Condition for Generic Pole Assignment by Output Feedback," Proc. of the 1983 IEEE CDC, San Antonio, Texas, December 1983, (to appear).

[11] T. E. Djaferis, A. Narayana, "Some New Results on Pole Assignment by Output Feedback," Technical Report UMASS-ECE-AUG83-1, (submitted for publication IEEE Trans. on AC).

[12] T. E. Djaferis, M. Das, H. Elliott, "Reduced Order Adaptive Pole Placement for Multivariable Systems," (to appear), IEEE Trans. on AC, Vol. AC-29, No. 7, July 1984.

[13] T. E. Djaferis, "Robust Pole Assignment," Workshop on Robust Control, Interlaken, Switzerland, October 1982, Technical Report UMASS-ECE-SEP82-1.

[14] T. E. Djaferis, "Robust Pole Assignment for Systems with Parameters," (to appear) Proc. of the 1983 IEEE CDC, San Antonio, Texas, December 1983.